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COMPUTER ANIMATION OF NASTRAN DISPLACEMENTS ON IRIS 4D-SERIES WORKSTATIONS: CANDI/ANIMATE POSTPROCESSING OF NASHUA RESULTS

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SUMMARY

The capabilities of the postprocessing program CANDI (Color Animation of Nastran DIsplacements) [1] have been expanded to accept results from axisymmetric analyses. An auxiliary program, ANIMATE, has been developed to allow color display of CANDI output on the IRIS 4D-series workstations. The user can interactively manipulate the graphics display by three-dimensional rotations, translations, and scaling through the use of the keyboard and/or dials box. The user can also specify what portion of the model is displayed. These developments are limited to the display of complex displacements calculated with the NASHUA/NASTRAN procedure for structural acoustics analyses [2].

INTRODUCTION

Animation of results has become an increasingly popular method of postprocessing because of the wealth of information conveyed to the analyst in a short amount of time. Animation allows the analyst to visualize time-dependent results that previously could only be imagined from a series of static plots. Through animation, the analyst is able to focus on the interpretation of the results, having been freed from the burden of envisioning their time dependency.

The advantages of animation were recognized by Lipman at David Taylor Research Center (DTRC), in the development of the postprocessing computer program, CANDI (Color Animation of Nastran DIsplacements) [1]. CANDI was originally written to interface with an Evans & Sutherland PS-330 interactive graphics system [3] for the graphics display. Unfortunately, the usefulness of CANDI was limited to those with access to this specific hardware.

A postprocessing tool was required for displaying complex displacements obtained with the NASHUA/NASTRAN procedure (hereafter referred to as NASHUA). NASHUA, developed by Everstine and Quezon at DTRC, is a coupled finite element/boundary element capability built around NASTRAN for calculating the low-frequency, far-field acoustic pressure field radiated or scattered by an arbitrary, submerged, elastic structure subjected to either internal, time-harmonic, mechanical loads or external, time-harmonic, incident loadings [2]. The structure can be axisymmetric or three-dimensional. CANDI was one postprocessing option for three-dimensional NASHUA analyses. An axisymmetric tool was also required.

Rather than replicate the work of Lipman, an auxiliary computer program, ANIMATE, was developed to accept, as input, the output from CANDI and display the results on the IRIS 4D-series workstations, manufactured by Silicon Graphics, Incorporated (SGI). The choice of the IRIS workstation was based on its three-dimensional, graphics display capabilities. CANDI was also expanded to postprocess results from axisymmetric NASHUA analyses.

Because the work described here was done to accomplish specific, programmatic needs, the scope of the computer program developed is limited to the display of complex displacements calculated with NASHUA. Although CANDI is able to postprocess results from other types of analyses, there are no expectations on the part of the author to enable ANIMATE to display these results. It is hoped that the foundations of the program are sound enough to allow enhancements by others, if needed.

THE NASHUA/NASTRAN PROCEDURE (NASHUA)

The NASHUA/NASTRAN procedure, also called the NASHUA capability or NASHUA, is explained, in detail, in Ref. 2. At Los Alamos National Laboratory, NASHUA is executed on a Cray supercomputer running under a CTSS operating system. Table 1 summarizes the steps involved in this type of analysis. Rigid Format 8 (direct frequency response) is used for each NASTRAN execution. All DMAP ALTER sequences are given in Ref. 2. The DMAP ALTER statements needed for the use of CANDI are the OUTPUT2 statements given in Figure 1. These OUTPUT2 statements produce a binary file, named ut1, containing the information needed by CANDI. To avoid the need for a file conversion program to move the ut1 file (in Cray binary) to another machine for postprocessing, CANDI was ported to the Cray.

TABLE 1
NASHUA/NASTRAN PROCEDURE SUMMARY

STEP	CODE	PURPOSE
1	NASTRAN 1	Define geometry Form structural mass, viscous damping, and stiffness matrices
2	SURF	Form fluid matrices
	NASTRAN 2	Set up coupled system for pressure
	OCSOLVE	Solve coupled system
	NASTRAN 3	Recover velocities
	MERGE	Combine multiple frequencies
3	FAROUT	Calculate far-field quantities
4	NASTRAN 4	Produce deformed structural plots
5,6, ...	IPLOT FAFPLOT CANDI, etc.	Perform additional postprocessing

```
ALTER       1 $ NASHUA STEP 4, COSMIC 1990 RF8
ALTER       8,8 $
ALTER       21,170  $
...
OUTPUT2     CASECC,BGPDT,ECT,FRL,PUPVC1//-1 $
OUTPUT2     ,,,,//-9  $
...
ENDALTER $
```

Figure 1. DMAP ALTER statements required for use of CANDI.

CANDI, THE POSTPROCESSING PROGRAM

CANDI is an interactive program that reads, filters, and outputs results from a variety of NASTRAN analyses, including static, eigenvalue, direct frequency response, direct transient response, and modal frequency response. It reads the binary utl file produced by including DMAP ALTER statements in the NASTRAN executive control deck. (For use with NASHUA, the specific DMAP ALTER statements are given in Figure 1.)

The user is asked a number of interactive questions to determine what output is desired. Figure 2 shows a sample interactive session. Through these questions, the user has control over what is displayed and how it is displayed. For example, portions of the finite element model can be excluded based on a range of XYZ coordinate values, on element type, and/or on element id. Coordinate ranges, element types, and element ids are displayed to assist the user. The user also has control over which results are output - which subcases and which frequencies, in the case of a NASHUA analysis. He also controls how many frames of animation are desired and whether the deformation scale factor computed by CANDI is used. The scale factor is computed so that the magnitude of the displacements will be similar to the dimensions of the finite element model.

Based on the responses, CANDI filters and outputs one or more ASCII files in vector list format. A sample vector list is given in Figure 3. To reduce the computational effort required by the display device,

```
xcandi
   candi - color animation of nastran displacements
   enter file name of the utl file ?
? utl

   coordinate limits of the finite element model
   xmin= 1.0000e-05       ymin= 0.0000e+00       zmin= 0.0000e+00
   ymax= 2.1695e+00       ymax= 3.3930e+01       zmax= 0.0000e+00

   do you want to exclude elements by coordinate ranges (y/n) ?
? n

   3 element type(s) (element type id-element type)
   146-cconeax            287-ctriaax        285-ctrapax

   do you want to exclude elements by element type (y/n) ?
? n

   do you want to exclude elements by element id (y/n) ?
? n

   do you want the vector lists to be
   1 - color coded by element type or  id
   2 - depth cued
? 1

   do you want to color code by element
   1 - type (not user-definable)
   2 - id (user-definable, default=blue)
? 1

   enter file name for the undeformed fem vector list ?
? undef

   do you want to generate any displacement vector lists (y/n) ?
? y

   number of subcases = 2, subcase ids -     1       2
   number of frequencies = 4   (number-frequency)
         1-  60.00       2-  70.00       3-  80.00       4-  90.00

   enter a subcase id and frequency number ?
? 2 3

   enter file name for the displacement vector list ?
? def3

   enter number of frames of animation ?
? 16

   maximum deformation = 2.1680e-03
   computed deformation scale factor (dsf) = 7.8253e+02
   do you want to change the computed dsf (y/n) ?
? n

   do you want to write another displacement vector list (y/n) ?
? n
stop
```

Figure 2. Sample CANDI session of axisymmetric analysis.

CANDI tests whether each side of an element has already been written to the vector list before adding it. The 'p' and 'l' designations are signals to the graphics device. A 'p' indicates 'move to' the given coordinates ; an 'l' indicates 'draw to' the given coordinates. The semicolon signals the end of the vector list. In this way, the undeformed (finite element model) and deformed (results) meshes are drawn efficiently.

```
aaa:=undeformed vec list
p-1.085e+00, 1.696e+01, 0.000e+00
l-9.160e-01, 1.696e+01, 0.000e+00
l-7.486e-01, 1.693e+01, 0.000e+00
l-5.842e-01, 1.690e+01, 0.000e+00
l-4.240e-01, 1.684e+01, 0.000e+00
                  . . .
;
```

Figure 3. Portion of vector list for undeformed mesh.

An axisymmetric version of CANDI was required. Structural acoustics problems frequently require fine mesh densities to capture the response of the structure accurately. Three-dimensional models become prohibitive because of computer time required for solution. Hence, axisymmetric analyses, when applicable, become extremely important. CANDI was enhanced to recognize the axisymmetric elements, CCONEAX, CTRIAAX, and CTRAPAX. Other elements could be added, given the knowledge of card type format[1] for each element desired. Additional information about CANDI can be found in Ref. 1.

ANIMATE, THE DISPLAY PROGRAM

ANIMATE was developed on a Personal IRIS®, Model 4D/25TG. It is written in C and uses the Graphics Library (GL) resident on SGI/IRIS workstations. ANIMATE reads the vector lists output by CANDI, calculates, and displays the animation sequence. Control of the display is provided through an extensive user interface. Specific aspects of ANIMATE are discussed in the sections that follow.

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[1]Card type formats are available in Section 2.3 of the "COSMIC/NASTRAN Programmer's Manual," NASA SP-223(5), August 1987. Header Word 3 is the element id number.

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HARDWARE / SOFTWARE REQUIREMENTS

The Personal IRIS, Model 4D/25 TG, on which ANIMATE was developed, was originally purchased for its three-dimensional capabilities with PATRAN®. The Personal IRIS (4D/20+) series give favorable price/performance curves. The need to animate complex displacements spearheaded the effort to port CANDI to the IRIS platform. In addition, other postprocessing tools for structural acoustics analyses had been developed for the IRIS 4D-series workstations.

The high-level Graphics Library made the graphics programming relatively easy. However, because the GL was used, ANIMATE is not universally portable. It is only portable to IRIS 4D-series workstations, or to IBM machines on which the GL has been installed. The IRIS Window Manager, based on the NeWS server environment was used to develop the user interface.

ANIMATE was initially developed using the dials box for the three-dimensional rotations, translations, and scaling. While the dial box is an intuitive method to accomplish these transformations, it is an optional peripheral. Therefore, the same functionality was tied to keys found on the standard IRIS keyboard. If available, use of the dial box is preferred.

The minimum hardware requirement to use ANIMATE is an IRIS 4D/20 G workstation. Any graphics workstation of the 4D-series is acceptable. The dial box is useful, but optional.

CALCULATION OF ANIMATION SEQUENCE

Animation of the harmonic time dependence of the complex displacements is accomplished according to the following equation.

$$F_i = V_u + DSF\ [\ V_{Re} \cos\theta_i - V_{Im} \sin\theta_i\ ]$$

where

where	F_i	=	ith frame of animation,
	V_u	=	undeformed vector list,
	V_{Re}	=	vector list of real components,
	V_{Im}	=	vector list of imaginary components,

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θ_i = angle for F_i = 360°/(number of frames),

and

DSF = deformation scale factor.

The equation is obtained by multiplying the time invariant result (here given by the complex displacements) by the appropriate time dependency. The simple harmonic variation of the results is given by the real part of this product [4]. For NASHUA, a harmonic time dependency of $e^{i\omega t}$ is assumed. Figure 4 illustrates this product graphically. One complete animation sequence corresponds to a 360° rotation of the complex displacement vector. Each frame of the animation sequence rotates the displacement vector by an angle of θ_i. For smooth animation, the number of frames, i, is normally specified between 12 and 16.

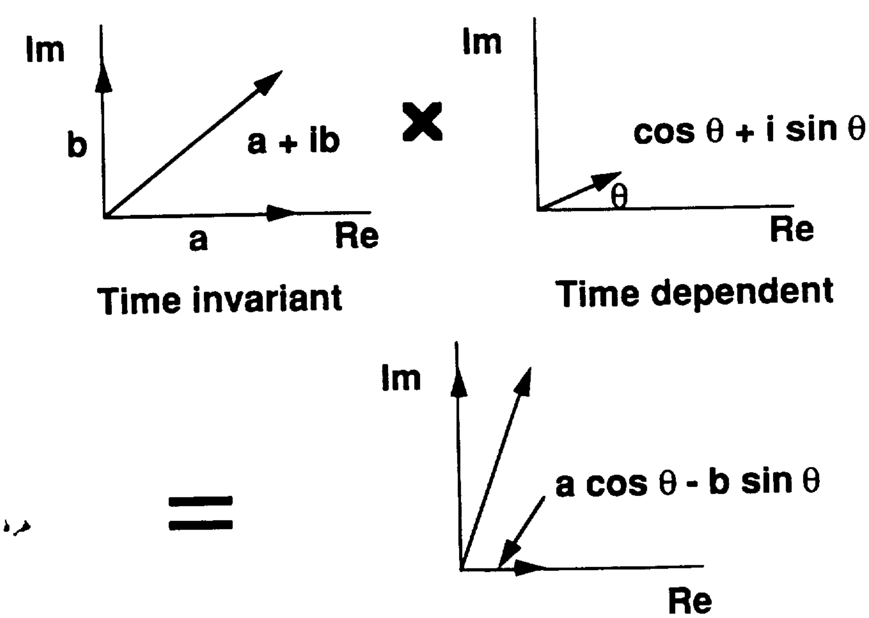

Figure 4. Graphic display of animation concept.

USER INTERFACE

It was important to develop a user interface that helped, not hindered the analyst. Thus, the interface was developed as intuitively as possible, maintaining the function key assignments found in the original CANDI/Evans & Sutherland system. Specific key assignments are listed in Figure 5. Dial assignments and locations are shown in Figure 6. Through this interface, the user has control over the view and scale of the model, the speed of animation, and the display of undeformed mesh and/or the coordinate axes. He can stop and start the animation, or step through it one frame at a time.

Function Key Definitions

FK1	Start animation
FK2	Stop animation
FK3	Step backwards through animation sequence
FK4	Step forwards through animation sequence
FK5	Slow down rate of animation
FK6	Speed up rate of animation
FK7,8	Not assigned
FK9	Reset all rotations and translations
FK10	Toggle on/off undeformed mesh
FK11	Toggle on/off coordinate axes

Other Key Definitions

x/X	Increase/decrease x-rotation
y/Y	Increase/decrease y-rotation
z/Z	Increase/decrease z-rotation
i/I	Left/right x-translation
j/J	Left/right y-translation
k/K	Left/right z-translation
s/S	Increase/decrease scale
ESC	Exit program

Figure 5. Keyboard definitions for user interface.

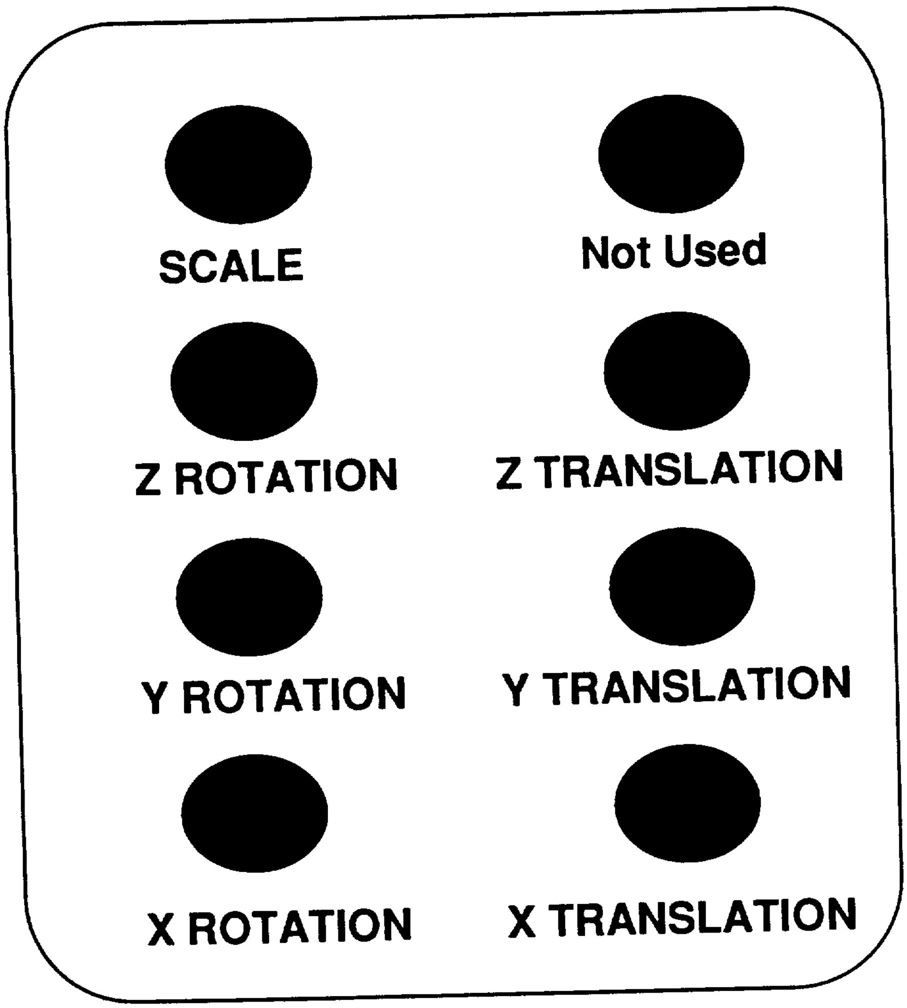

Figure 6. Dial box definitions and dial locations.

REFERENCES

1. R. R. Lipman, "Computer Animation of Modal and Transient Vibrations," Fifteenth NASTRAN Users' Colloquium, NASA CP-2481, National Aeronautics and Space Administration, Washington, D.C., pp 88-97 (May 1987).

2. G. C. Everstine and A. J. Quezon, "User's Guide to the Coupled NASTRAN/Helmholtz Equation Capability (NASHUA) for Acoustic Radiation and Scattering," Third Ed., DTRC report CMLD-88/03 (February 1988).

3. "PS-300 User's Manual," Evans & Sutherland Computer Corporation, Salt Lake City, Utah, 1985.

4. F. Fahy, Sound and Structural Vibration, Radiation, Transmission and Response, Academic Press, 1985.